Heterophoria

ıe Memorial Lecture of the
Oxford Ophthalmological Congress 1921

By

ERNEST E. MADDOX, M. D., F. R. C. S. ED.

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Doyne Memorial Lecture of the Oxford Ophthalmological Congress 1921

Ernest E. Maddox, M. D., F. R. C. S. Ed.

THE founder, and first "master" of this Congress, Mr. Robert W. Doyne, was an exceptionally ardent benefactor of ophthalmology. To him Oxford practically owed its Eye Infirmary, and the University its diploma in Ophthalmology.

The early meetings of the Congress are alive with memories to many of us, of his genial presence, setting everyone at ease, even including, to our admiration, those unfortunate if honoured patients upon whom members of the Congress were allowed to operate!

On later occasions, the scene changed, and 'pathos' entered. The well-knit frame, inured to manly sports, had been manifestly overworked (for he did the work of two men) and we saw the evening time of life gathering about him all too prematurely; illustrating how

> "Swift to its close ebbs out life's little day,
> Earth's joys grow dim, its glories pass away."

Among many other mementoes, he has left this Congress behind him but not without first committing its welfare to the able hands in which it has continued to prosper.

Introduction

We owe the name, and most of the classification, of heterophoria (which means a 'tendency to differ'), to George Stevens, of New York, whose English ancestors, it is interesting to note, were ancient benefactors of Wadham College, Oxford. For twenty years before his day, hetero-

phoria was studied under other names, such as 'insufficiency' and 'latent deviations,' under the presiding genius of von Graefe, and I notice in the literature that even what we now call hyperphoria was corrected by Mr. W. A. Brailey, more than forty years ago.

Heterophoria is a tendency to imperfection in the oculomotor apparatus, so let us first glance at that apparatus itself. To begin with, there are several things it shares in common with the rest of nature, viz. *on* the surface diversity and beauty, and *under* the surface, unity, balance, habit and rhythm.

The diversity of nature is very evident, but the underlying unity is just as real. Gravitation, for instance, binds the whole universe in one, while radiant energy everywhere fills it with light and warmth. The same laws of motion which guide a schoolboy's marble, are implicitly obeyed by the remotest planet. This principle of diversity in unity is found in every *object* of nature, for the small reβects the great. It is strikingly so in living organisms, ane is particularly well seen in the eyes. The cerebral hemispheres make the brain appear double, yet it is really one, and the eyes are windows (also two in one) through which that most deeply hidden of all the systems, the central nervous system, comes to the surface to look out upon the world. It is no wonder, therefore, that Hering long ago described the eyes as a *single organ with two limbs*. This single organ he called the 'Doppelauge' and located it virtually behind the root of the nose. I have ventured to name it the 'Binoculus' as more easily pronounced. Pictures on the maculae are normally referred to the line which connects the Binoculus with the point of intersection of the visual lines. You may ask; "If the eyes are virtually one, why are there two?" The duality of the eyes is necessary for *stereoscopic* vision, to give us two points of view meeting in one; for a wider field; for *safety* in the event of accident or foreign body; for *beauty* (for could you imagine yourselves proposing

to a cyclopean young lady? or a lady with three eyes?), and lastly for silent *eloquence;* for eyes can speak, and, as the poet expressed it, "Soft eyes spake love to eyes which spake again." Together with the lids and eyebrows, the eyes express the passing emotions, as a silent lake reflects the changing sky. Just as the mind is linked with the cerebral cortex, so, it would seem the emotions are linked with the vegetative nervous system, and the eyes are linked with both, for they express both thought and emotion. Their link with the vegetative system is well shewn by the gastric disturbance so invariably met with in acute glaucoma; and conversely, an ice-cream, as Lucien Howe mentions, will often cause a brow-ache. This "reverse action" has a great bearing on heterophoria, for we may sometimes consider it the cause of symptoms when itself is caused by visceral irritation. As regards the muscles, nerves and terminal motor nuclei the eyes are two, but with respect to all higher neurons they are one.

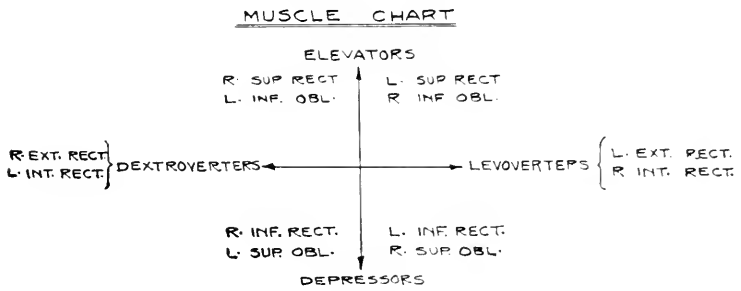
It is a most important clinical distinction that all affections of the final common paths are non-comitant, while all those of higher structures are comitant. Hence in the presence of comitancy we cannot use such expressions as 'weakness of the interni, of the superior recti, the obliques,' or the like. It is not that such conditions are impossible, but if they are present non-comitancy is present. If the internal recti were weak there would be increase of the defect on looking to either side; if the superior recti, there would be hyperphoria on looking to one side, and the opposite hyperphoria on looking to the other side, and similar 'alternating hyperphoria' as we might call it, would be in evidence if the superior or inferior obliques were weak. *Every intraorbital explanation of comitant deviations must be fallacious.*

Divisions of Heterophoria

The first great division of heterophoria, therefore, is

into what I would call 'lower' and 'higher' heterophoria, according as it is non-comitant or comitant. It is clear that we need two different kinds of charts, one for the muscles (Chart I) and one for the reflexes (Chart II), and we need to be somewhat on the alert to know which chart is appropriate to a special case. I believe all reflexes act through the higher neurons. No single muscle is affected by a reflex.

CHART I



Lower heterophoria—that is, heterophoria due to one or more affected muscles—is, I think, very often over-looked, because we are so much in the habit of confining our measurements to the primary position where it may not show itself. The four diagonal areas of the motor field are easily investigated by the disc of rods, the patient's head being placed in the required obliquity before a large tangent scale on the wall. If the disc is not held quite in a vertical plane, however, the red streak appears curved, which may vitiate the test. To guard against this I employ a disc swung as from a gallows, which hangs truly without being able to rotate about a vertical axis. I find this extremely suitable for measuring the torsion of the false image, and I have asked the makers of my tangent scale to let the scale be fixed to the wall by a single screw at its centre of gravity, to allow of its rotation by an assistant,

CHART II

Oculomotor Reflexes

(Suggested Classification)

KINGDOM 1: OR HOME OFFICE (To Create the Binoculus)	
HORIZONTAL	1 Convergence (Eyes approximate). 2 Divergence (Eyes separate).
VERTICAL	3 Right Hypervergence (R. rises & L. falls). 4 Left Hypervergence (L. rises & R. falls).
TORSIONAL	5 Incyclovergence (Both twist in). 6 Excyclovergence (Both twist out).

a Function = Fusion
b Prevent diplopia
c Unify the eyes
d Take account of third dimension of space and give consciousness of distance of objects
e Involuntary
f Motions contrary
g Stimulus = Desire for single vision
h More linked with the vegetative system
i Meissner's torsion

KINGDOM 2: OR FOREIGN OFFICE (To direct the Binoculus)	
HORIZONTAL	7 Dextroversion (Both turn to left). 8 Levoversion (Both turn to left).
VERTICAL	9 Surversion (Both rise). 10 Deversion (Both sink).
TORSIONAL	11 Dextrocycloversion (Both twist to right). 12 Levocycloversion (Both twist to left).

a Function = Fixation
b Powerless with diplopia
c Direct the gaze
d Take account of first and second dimensions of space and give consciousness of direction and attitude of objects
e Mostly voluntary
f Motions parallel
g Stimulus = Desire for macular perception
h Linked with labyrinths, and somatic equilibrating system
i False torsion

until it is parallel with the streak of light. A weak vertical prism before the other eye, or clipped on to the disc of rods, makes the test easier. I sometimes use a rotating wand attached to the wall, or to an old Bjerrum screen, by a nail through its centre. The diagnosis of paretic muscles is, of course, made on the same principles as for frank paralysis. I still think that, for the vertically acting muscles, the best method is that outlined in my book on the *Ocular Muscles*, namely: to make the diagnosis from the vertical separation only, and then confirm it by the torsion, leaving the horizontal element out of account.

Let us now consider *higher heterophoria*. I would like to draw your attention to the twelve beautiful reflexes of which I believe six preserve the eyes in one, while the other six make them dance hither and thither like a pair of merry children hand in hand. Some of them are familiar to you, others probably not. They are in six reciprocal pairs, on the "give and take" principle, and they no doubt have the "reciprocal innervation" discovered by Sherrington.

Hering took account of only five motions in framing his theory, and modern text-books of physiology enumerate no more, but in ophthalmology, others have gradually made themselves evident during the last thirty years, and I think now all these twelve are definitely proved, except the second, in favour of which two reasons might be given, and two against. I have tried to classify them into natural orders, as shewn in this chart.

Another list, I ought to say, has been made by Professor Savage of Nashville, a list of ten, but differing from mine as being on the lines of lower heterophoria instead of higher; that is to say they are in terms of the muscles. The most interesting division I have found of the twelve reflexes is into two kingdoms or groups, one of which might be called the 'Home Office,' since its function is to settle the domestic differences of the eyes; and the other the 'Foreign Office' since all its interests are abroad. In the former the motions

are all mutual, *i. e.* towards or away from each other; in the latter, all parallel. These two groups never usurp each other's functions, and yet work in perfect harmony. They are like a white man and a black man working harmoniously at two ends of one saw, and yet the white man always white, and the black always black. Indeed, what Hering found true of convergence and the lateral movements of the eye may be extended I think to the whole of each kingdom.

The third dimension in space is the only one that interests the 'Home Office,' while the 'Foreign Office' is exclusively concerned with the first and second dimensions. The 'Home Office' effects fusion, the correction of diplopia, and the formation and preservation of the binoculus. It cannot direct the binoculus in the smallest degree. The 'Foreign Office' alone can do that and is concerned with fixation, orientation, equilibration and version. The 'Home Office' acts under the stimuli of threatening diplopia of six different kinds. The 'Foreign Office' is powerless to correct the smallest diplopia of any kind and acts under the stimuli of volition from above, combined with a subordinate fixation reflex from below. Miners nystagmus is, I believe, largely due to a conflict between volition and the fixation reflex, since the glitter on the coal solicits the latter while a blow is being voluntarily aimed at a non-glittering spot. This is only by the way. I think you will find the 'Home Office' is more in touch with the vegetative nervous system, and the 'Foreign Office' with the somatic nervous system and the labyrinths. This is a very interesting distinction if true, explaining why worms, indigestion, and teething, cause not parallel deviations, but squints, and I have definitely proved my own slight esophoria to be increased by gastric irritation.

These two kingdoms may therefore be looked upon as two compound reflexes, playing a duet, as it were, upon the terminal nuclei of the twelve ocular muscles. They never strike single notes, but always *chords*. That is to say they

never actuate single or even pairs of muscles. Now, I have no doubt, since the same chords have to be struck again and again, that linkages are formed between even the oculomotor nuclei of the 3rd, 4th, and 6th nerves, to mechanicalise the work, just as linkages are opened up to the spinal cord for the fingers. For indeed the lower motor neurons of the ocular muscles are in series with those in the anterior horns of the spinal cord, just as the ciliary ganglion is in series with the prevertebral ganglia.

The Reflexes

The first reflex (to take them now in detail), is an old friend, viz: that for *convergence*, the slackness of which causes exophoria, and its excess esophoria. (I prefer the English pronunciation to the Greek (esophoria) as distinguishing the sound better from exophoria.) Fig. 1 shews how the visual lines are approximated towards the point of fixation by accommodative convergence, aided by postural habit. This is the coarse adjustment. The small bracket represents the fusion reflex which effects the fine adjustment. It not only makes the lines meet, but fastens them together.

You may wonder what is meant by the larger bracket. It represents a fusion-reflex augmented by voluntary effort. The arrow above it represents directed energy from above, perhaps from the angular gyrus, which Gordon Holmes has shewn to be connected with visual attention.

However great the postural defect may be, if compensatory hypertrophy has made the fusion reflex large enough to easily overcome it, the heterophoria may be regarded rather as a harmless anomaly than as a pathological symptom. But the moment the work to be done is almost as great as the workman, the latter begins to labour, and trouble begins. The fusion reflex then borrows energy from the centrons of neighbouring reflexes, and from the cerebral cortex, in the form of the 'forced attention' referred to.

Now a reflex is a machine, that is to say, a labour saving

device, far more economical than voluntary effort. Sherrington has shewn how especially untiring are the postural reflexes connected with the gravity muscles and no doubt

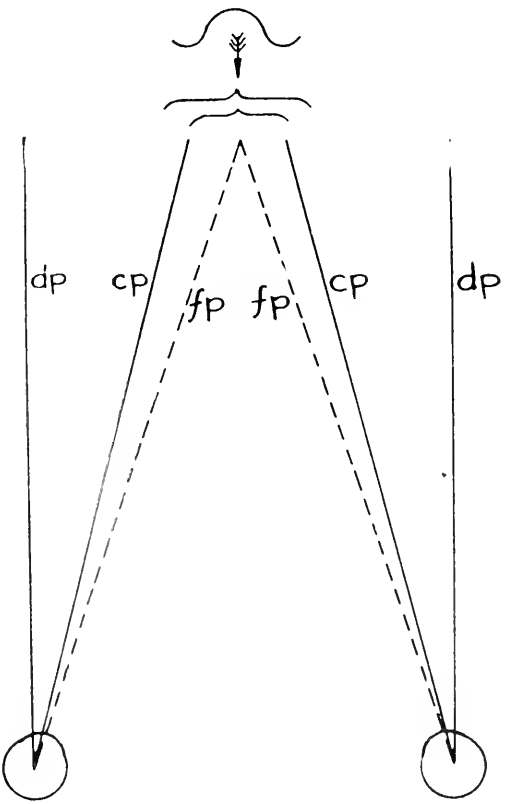


Fig. 1. The coarse and fine adjustments of convergence. Distance posture *d p*. Convergence posture *c p*. Fusion posture *f p*.

something similar could be said about those of the eyes, especially of the Home Office. We have lately heard from him that the katabolic waste of voluntary motion is half a million times greater than of these postural reflexes.

Whether the figure is correct or not it at least makes us think. The cortex is the last part of the brain to mature, and the first to fail, and its exercise is the most tiring. The angular gyrus lies pretty far back, and the cerebellum has so much to do with these reflexes that the frequency of occipital headache in uncompensated heterophoria is not surprising, especially if the ablo-ascoid muscles are also wearied.

Since convergence is the strongest and most trainable of all the reflexes, its slackness (called exophoria) rarely needs treatment by prisms. Its link with accommodation enables us to influence it by spherical lenses, a treatment which next to constitutional measures, is the best. The correction of astigmatism also, and of hyperphoria, helps to preserve the converging reflex from being robbed of its energy. For esophoria we use lenses which *fully* correct hypermetropia. For exophoria, generally those which *partially* correct it; but not always, for in neurasthenia a full correction may be best. "Exophoria with hypermetropia" has always been a great puzzle, but I think it due to a limited amount of nervous energy, of which so large a share is needed for accommodation as to leave too little for convergence. For many years I have treated exophoria in healthy young people by concave lenses, so as to invoke even superphysiological exercise of accommodation, and thus harness their abundant accommodative energy to the task of sensitising the converging reflex.

The *diverging* reflex (No. 2) is the only one I have not been able to positively prove. Exophoria from "divergence excess" is still only a theoretical conception. It is moreover almost impossible to distinguish between inhibitory neurons, acting on convergence, and a positive reflex acting on the external recti as its effectors. However, the analogy of the other reflexes disposes me to believe in the latter. Indeed, I suggested, thirty-five years ago, in the *Journal of Anatomy and Physiology* that the external recti were in-

nervated by the sympathetic in antagonism to convergence, just as the dilator pupillae antagonises the sphincter. In any case, there must be some mechanism, the proper stimulus of which is threatened homonymous diplopia, and which when damaged by haemorrhage causes sudden convergent strabismus. So I have ventured to include it in my chart, with all deference to Sir George Berry's able arguments otherwise. Convergence may possibly be governed by vagotonic fibres if my thought of sympatheticotonic control of divergence is correct.

I think all the reflexes of Kingdom I are (to borrow Sherrington's term) *postural*, and those of Kingdom II *phasic*. Certainly the vergences are less powerful than the versions. I have sometimes thought they are slower. The modern theory that the sarcoplasm is controlled by the sympathetic, and the sarcostyles by the voluntary motor nervous system may if true have a bearing on the two main groups of oculomotor reflexes.

Nos. 3 and 4 are remarkable reflexes, which I believe to be of a *see-saw* nature. I have chosen the name hypervergence, not because it is the best, but to be in a series with hyperphoria. If a prism is held erect before one eye to test the prism vergence, that one eye rises to overcome it, I believe, by one of these see-saw reflexes, in combination with the surverting reflex No. 9 which simultaneously raises both eyes equally, to preserve the naked eye from displacement. This arrangement looks so needless and complicated and it would be so much simpler for each eye to have the power of monocular adjustment (Prism-duction), that for many years I only mentioned these see-saw reflexes as probable in spite of the skew deviation of the eyes sometimes noticed when the middle peduncle of the cerebellum is damaged, until one day I had a remarkable patient who later went by the name of 'Old See-Saw,' for one eye rose as the other fell, in large regular, slow sequence. This settled my last doubt. A little consideration will shew that such an arrangement must

be, if each of the two Kingdoms is to be true to itself. This figure (Fig. 2) shews what would happen were right hypervergence to take place by itself, while Fig. 3 illustrates the sim-

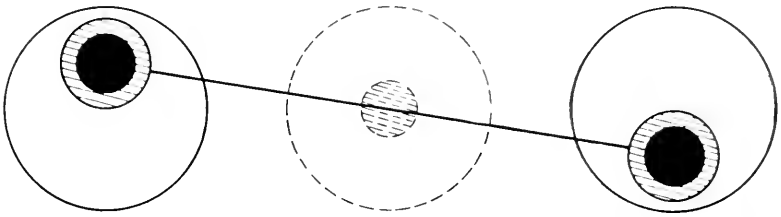


Fig. 2. To illustrate the "see-saw" motion of right hypervergence. (Note immobility of Binoculus)

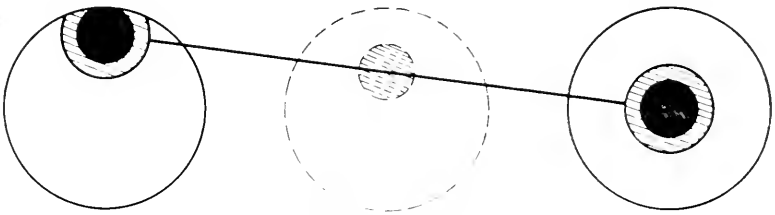


Fig. 3. Combined right hypervergence and (binocular) surversion. (Note rise of Binoculus)

ultaneous surversion of both eyes, by reflex 9. In the first figure the 'Binoculus' remains stationary; in the second it is raised half as much as the right eye, so that objects appear displaced upwards, through half the deviating angle of the prism, and this I have proved to be the case. It will be noticed that the see-saw motion alone leaves the Binoculus unmoved. It is most important that the mind should be sensible of every movement of the Binoculus, and since Kingdom I is incapable of imparting such sensation, it defers all movement of the Binoculus to Kingdom II. Herein we detect the reason for an arrangement which appears needlessly complicated. It enables each kind of reflex to mind its own

business, and to supply correct information to headquarters.

The normal function of the see-saw reflexes is to preserve the fixation lines in the visual plane. When we wear cylinders with oblique non-parallel axes, the see-saws are in constant alternating exercise as we look from side to side, since the prismatic effect of the lenses is such as to cause alternating hyperphoria. This is one of the chief reasons why oblique cylinders are so ill tolerated.

Since the hyperverging reflexes are of small amplitude, hyperphorics are nearly always grateful for correction by prisms. They are the least trainable of all the reflexes.

The *cycloverging* reflexes (5 and 6) cause the vertical axes of the eyeballs to mutually incline towards or away from each other. They act rather more on the obliques than on the recti, but so as to be thoroughly comitant in their effect, which could not of course be possible were they to act on the obliques only. They not only correct cyclophoria but have I believe an extremely interesting part to play in ordinary vision, for, if I am right, they enable the retinal images of sloping lines in the median plane to fall upon corresponding meridians. If I hold this penholder in the median plane, but with its upper end further from me than the lower, reflex 6 (excyclovergence) comes into play, otherwise I should see the pen double, with images crossing, while if the slope of the pen be reversed, so as to bring its upper end nearer to me, reflex 5 (incyclovergence) is active.

It is well known that when two arrows are depicted diverging above on a stereoscopic card they appear, when fused, to shoot away from the observer, but when diverging below to shoot towards him.

Cyclophoria in distant vision is easily measured by the glass rods as already described, or by cyclophorometers, and the result is sometimes valuable in helping us to decide which muscle to select for an operation. In my own eyes there is slight excyclophoria when fatigued, as by a long walk. In the year 1890 George Savage discovered the prev-

alence of excyclophoria in near vision while experimenting with my double prism, and seven years later George Stevens published his first paper on declinations. More than sixty years ago, however, a torsion of the eyes in near vision was greatly studied by Meissner (1858), Volkmann, Helmholtz, and others, and later by Le Conte.

I will now invite you to make an experiment yourselves. Draw an upright arrow or line on the back of your programmes, and hold it closer to your eyes than the near point of convergence so that you see two arrows. In all probability they diverge above, shewing excyclotropia, since the images are crossed. If now you raise the paper so as to look under your eyebrows the mutual slant increases, but if you lower it so as to look down as far as possible, the arrows become parallel. This proves that in near vision there is a physiological excyclophoria, except on looking down, and that it gradually increases as the eyes are raised, and also, it may be added, as the object of fixation is brought nearer. We learn from this, what Helmholtz pointed out from Meissner's test, that in near vision the primary position of the eyes is one in which the visual plane is depressed, and indeed, we naturally cast our eyes downwards for near objects to let the hands and eyes work together.

If now you look at the same arrow with the eyes turned up to the right, you may notice one arrow rise higher than the other, while with the eyes turned up and to the left, the other arrow may rise. In my own case the rising arrow indicates an alternating hyperphoria which points to comparative inaction of the superior recti as a partial cause of the cyclophoria, so that it may have both a "higher" and "lower" element.

Before leaving the subject of cyclophoria I might mention that in Professor Savage's list, the place of these cycloverging reflexes is taken by what he calls "harmonious symmetrical action of the obliques"; but I would suggest that harmonious action of the obliques is impossible. They would cause

CHART III
Conjugate Oculomotor Nomenclature

KINGDOM I. OR HOME OFFICE			
	MOTIONS.	PHORIAS.	TROPIAS.
1	Convergence	Esophoria	Esotropia
2	Divergence	Exophoria	Exotropia
3	R. Hypervergence	R. Hyperphoria	R. Hypertropia
4	L. Hypervergence	L. Hyperphoria	L. Hypertropia
5	Incyclovergence	Incyclophoria	Incyclotropia
6	Excyclovergence	Excyclophoria	Excyclotropia
KINGDOM II. OR FOREIGN OFFICE			
	MOTIONS.	PHORIAS.	TROPIAS.
7	Dextroversion	Dextrophoria	Dextrotropia
8	Levoversion	Levophoria	Levotropia
9	Surversion	Anaphoria	Anatropia
10	Deversion	Kataphoria	Katatropia
11	Dextrocycloversion	Dextrocyclophoria	Dextrocyclotropia
12	Levocycloversion	Levocyclophoria	Levocyclotropia

Vergences are contrary motions of the eyes (mostly involuntary).

Versions are parallel motions of the eyes (mostly voluntary).

Prism-vergences are changes effected in the mutual posture of the eyes by prisms which are "overcome."

Ductions are drawings of a single eye in any direction by its muscles.

Torsion means twisting of an eye about its own fixation line = wheel-motion.

Cyclovergence means mutual contrary wheel-motion of the two eyes; **cyclotropia** the result; and **cyclophoria** the tendency thereto.

Declination means angular departure of the vertical axis of one eye from parallelism with the median plane of the head.

Phorias are "tendencies" checked in Kingdom I. by the fusion reflex; and in Kingdom II. by the desire to keep the head straight.

Tropias are "turnings," causing in Kingdom I. squint; and in Kingdom II. inclinations of the head.

The prefixes **sur** and **de** are contractions for "sursum" and "deorsum" (compare surmount, deject, etc.).

"alternating hyperphoria," for on looking to the right or left the elevating power of the ipsolateral obliques lessens, and that of the contralateral obliques increases. At the same time it is pleasant to own that his theory aimed at the true thing; it only needs translating from lower or incomitant, into higher or comitant heterophoria to be correct.

The first four reflexes of Kingdom II are too well-known to be dilated upon. They were named "versions" by Duane. I have ventured to shorten the awkward prefixes 'sursum' and 'deorsum' into 'sur' and 'de.' These parallel motions are both voluntary and reflex. In their defects no diplopia can be elicited by the glass rod. There may be a limitation of version, *i. e.* of parallel movements of the eyes, in one direction, or there may be merely a preponderance of one reflex over its antagonist. I regard it as a phoria if there is no vicarious inclination of the head. If the head be turned to save the weak verting reflex it is, I suggest, no longer a case of phoria but of tropia. Stevens made a great study of anaphoria and kataphoria (but without making this distinction), and more recently Valk has written, well and ably, on dextrophoria and levophoria, as studied by Stevens' troptometer. As so many become confused about nomenclature, I have drawn up chart No. III.

The *cycloverting* reflexes (11 & 12) incline the vertical axes of the eyeballs parallelwise to right and left. They are, I am satisfied, well proved, and even their amplitude can be, to some extent, measured. They enable us to judge of the erectness of objects. When we look at a picture, for instance, to see if it is straight on the wall, we instinctively incline our heads slightly to one side and the other to put these reflexes on the 'qui vive.'

It is only in this indirect way that they might be called voluntary. They are also involuntary steadiers of the eyes in its other parallel movements, but they do not, as some might suppose, either cause or nullify "false torsion" for that

is already perfectly accounted for, as a simple mathematical necessity, by composition of the vertical and horizontal parallel movements of the eyes.*

Lucien Howe, author of the most complete textbook on the *Ocular Muscles*, has suggested a number of other innervations for the oblique movements of the eyes, but as I cannot discover these, I have not charted them.

Tests for Heterophoria

Let us now consider a few *tests* for heterophoria. That which first of all led me to pay attention to muscle balance, was the discovery, while experimenting with two pin holes in a piece of paper, that I had a slight esophoria for distance. To investigate this more fully, and at the same time find out how one eye would behave if placed in the dark, I constructed this dark box nearly forty years ago, and it was kindly shewn by Mr. Nettleship to the Ophthalmological Society. Its aim was to utilize the blind spot to record the movements of a darkened eye. I found by its use that I had an exophoria of about one metre angle in near vision and to my surprise a great many others had similar deviations of varying degree, so much so, that for a time I called it "physiological exophoria," a name which I have now abandoned since it might make the numerous exceptions which occur, especially in young people, to be thought unphysiological. Von Graefe's test for near vision, till then universally employed, consisted of a dot with a line through it,

*Professor Savage has published a theory that in the oblique movements of the eyes, the vertical axes of the eye-balls are preserved in parallelism with the median plane by 'harmonious non-symmetrical action' of the obliques, that is to say, the right superior oblique working with the left inferior, and the left superior with the right inferior. I regret my inability to endorse the views of so earnest a worker, for to begin with, the vertical axes of the eye-balls do become inclined to the median plane in the oblique movement of the eyes as a necessary consequence of Lishing's law, just as the horizontal axes become inclined to the horizontal plane in the opposite sense: and secondly any such combined action of the pairs of obliques named would result in a vertical squint. For example, if the right superior oblique were to act with the left inferior oblique, the right eye would sink and the left rise.

reduplicated by a prism, base down before one eye. It did not seem to occur to von Graefe that the overlapping of the portions of the line would suffice to maintain fusion, so that his test only revealed deviations in extreme cases, and led to the belief that the normal relation between convergence and accommodation was a fixed one. I must resist the temptation to describe a number of other experiments with this box from which indeed I learned most of what little I know about oculomotor physiology. A better way of using it is to disregard the blind spot and make the two points of light appear one over the other when the deviation can be read off direct. Its findings were confirmed by two other tests; which occurred to me all the same time, namely: the double-prism and the arrow tangent-scale, both of which were much used for some years until the first begat the rod-test, and the second the wing-test. Perhaps the prettiest appliance I have made is the twin-test, consisting of two celluloid sheets of complementary colours in apposition, and so pricked through that designs appear which can be brought to coincide. My near vision phorometer also in complementary colours is quite good if well made, but I have not brought it today, for neither method secures the accommodation quite so well as the wing-test. I find in practice that, on the principle of the survival of the fittest, I have gradually dropped all other tests except the rods for distance, and the wing for near, supplemented by the redress and the parallax tests (the latter so ably advocated by Duane), and my prism-verger occasionally. I think no refraction is complete without measuring both the distant and the near posture. The rod-test you probably know already; I like it made with very thin rods, and not too small in area. It is best used in a room dark enough to avoid adventitious reflections, and yet with enough light to secure accommodation. I have in my own eyes esophoria of 1°, but if one eye be screened I have a ½° only. I have found many both in far and near vision have about ½° less esophoria, or ½° more

exophoria, on screening. This is due to slackening of the converging reflex when one eye is completely covered. In the wing-test both eyes receive a natural stimulus to accommodation. I have crowded the wings close to the eyes for horizontal measurements to avoid exciting the ciliary muscle, for objects which are hopelessly near do not tempt accommodation. It is important to make sure that the apparatus is correctly made, so that the object intended for each eye is entirely hidden from the other. I have provided the rotating wing-test with a means of measuring cyclophoria, both by vertical and horizontal lines, using the distant pillar for the first, and the wings set nearer and cross-wise for the second. You will generally find a difference between the two measurements, due at any rate in part to the curious fact investigated by Helmholtz and others, though denied by Savage, Stevens, and Le Conte, that the physiological dividing line between the two lateral halves of the retina is not perpendicular, but slants down and in. I have investigated the point and I find the "Helmholtz retina" exists in most eyes, but not in all. The 'wing-test' is of great service in the correction of presbyopia. If the arrow trespass ever so little on the esophoric side, we may safely increase our correction, while an unusual degree of exophoria will make us careful to keep it as weak as we can without loss, though of course other considerations come in as well. The most important minute of a refractive consultation is that in which we deliberate what reading lenses to order.

The 'wing-test' can also save us sometimes from over-correction of hyperphoria. We may, for example, find 2° for distance and about 1° in near vision. For hospital use, my rotating pattern is rather fragile, and I have for many months tried to puzzle out an instrument free from all movements, and therefore stronger. I have at last succeeded. One fixed chart now measures the horizontal vertical, and torsional elements all "in one go." After the horizontal balance has been measured, the arrow should be set at an angle that

makes it appear horizontal to the patient. Then we can read off the hyperphoria and the cyclophoria.

Treatment of Heterophoria

The treatment of heterophoria becomes a simple matter as soon as we thoroughly understand the nature of a case. Each needs taking on its own merits. I need only touch on some elementary principles.

1 Discover the cause and remove it if possible.

2 Correct any error of refraction with perhaps a little decentering of the lenses in the direction of relief. At the same time treat the constitution with any necessary advice as to regimen and the use of the eyes. If symptoms entirely disappear, no more need be done, even if the heterophoria remain. It will almost certainly be less in time, since every organism tends to "come to itself" when freed from adverse influences.

3 If lateral deviations are complicated by hyperphoria correct the vertical deviation first and the lateral will very likely correct itself.

4 If after the above treatment some symptoms still continue, train the weak reflex or the weak muscle as the case may be. Training is chiefly indicated in young people. It is only suitable for older ones when they are possessed of sufficient vigour. In neurotic or neurasthenic cases it should not be commenced until the nervous system, both ocular and bodily, has been strengthened, and should be commenced during a holiday or bracing change. Undue recession of the convergence near point (or sub-convergence as I like to call it) can be trained by drawing an arrow on a piece of paper and approaching it to the eyes again and again while endeavouring to keep it single. Reber's lateral version exercises may help somewhat, in the same way that rowing helps writers' cramp, by bringing fresh blood to the structures concerned without actual exercise of the weakened neurons. Prism exercises come next. I often give young people a

second pair of spectacles resembling those they wear, but with adverse prisms incorporated, and bid them wear these training spectacles at certain favourable hours of the day. As an alternative to this, one or two "grab" prisms can be slipped on to the spectacles in ordinary wear. Whenever the prisms are more easily overcome in near than in distant vision they can begin by looking at a point on the wall close up to it and then receding backwards to the other end of the room repeating this again and again early in the morning or after breakfast or rather before the eyes are tired. When glasses are not worn I order prisms set in circular rims, so that as the reflex is strengthened, the base-apex lines can be made to lie at greater and greater angles to each other by rotating the prisms in the frame. Lastly, the most powerful training of all is obtained by the simultaneous rotation of two prisms as in my prism-verger, the object being a disc of ivory or white paper in the centre of a Bjerrum screen. My verging prisms (*i.e.*, rotating towards or away from each other), can be conveniently mounted also either in a phorometer or in a stereoscope. Training in the consulting room however is only practicable for those surgeons who are blest with sufficient leisure.

5 Operation. This generally is the last resort after we have helped nature to do her best. It is invaluable in some cases and especially when we can convert a non-comitant deviation into a comitant one (Duane). Hence before operating, the whole field should be measured to find a weak muscle, the operation should be planned so as to simultaneously correct any cyclophoria, and in lateral deviations any hyperphoria. Lastly, the strength of the opposing reflex should be measured by prism-vergence, especially for a tenotomy. I say the opposing *reflex* because it is not enough for the opposing *muscle* to be strong. (For example, however strong the internal rectus may be, we shall obtain no effect from tenotomy of the external in the primary position if the converging reflex is inactive. The internal rectus may be

strong for phasic motions, and yet the posture be weak.) Exercise of the convergence, however, may often be trusted to bring about a sufficient augmentation of the reflex to make tenotomy advantageous. I have had excellent results from graduated tenotomy of an inferior rectus for old standing paralysis of the opposite superior oblique (restoring the head, for example, in the case of one medical friend to the erect position, after being tilted for years toward one shoulder). Even cyclophoria is sometimes worth operating for. I have recently seen a patient on whom I operated for this more than twelve years ago. Previously to the operation he had headache without intermission for seven years dating from typhoid, and he has had no headache since. But these operations are extremely tricky, and in higher heterophoria it is rather a responsibility to convert a comitant defect into a non-comitant one by operation. Here again, however, nature comes to the rescue, and gradually restores more or less comitancy if a muscle is only tenderly dealt with by operation, on the principle of "reversion to organism" as we might call it.

The most successful surgeon is the one who respects nature most. You may perhaps wonder that I have said nothing about the evolution of the oculo-motor apparatus, but, gentlemen, when I look at your intelligent faces, and the soul in your eyes, I cannot bring myself to believe that you are descended from maggots and spiders and pigs. The whole voice of nature, as I hear it, is against that fantastic theory. Nature is conservative and not progressive. She reverts to type as soon as the reason for departure from it disappears. When I see a piano, I do not at once jump to the conclusion that because the keys are in progressive series, therefore they must have evolved out of one another!

I thank you, gentlemen, for your kind attention, and I have now the pleasure of laying this imperfect lecture as a little memorial wreath upon the tomb of our friend and benefactor, Robert Walter Doyne.

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